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A RECORD OF WINTER KILL OF THE WESTERN PINE BEETLE IN CALIFORNIA, DECEMBER, 1932

Introduction

The cold spell which occurred in the Pacific Coast region from December 9 to 14, 1932, brought temperatures that were lower and and continued over a longer period than any that have been recorded for a number of years. In some sections of California, where tree growth had been accustomed to mild winters, injury resulted, such as the killing of eucalyptus foliage in the San Francisco Bay district and in the interior valleys. In some of the forest sections of the State, however, these freezing temperatures were low enough to cause high mortality of tree-killing bark beetles, and in that respect promise to be of considerable benefit.

Shortly before this cold snap the Badger Springs Control Project, Modoc National Forest, was initiated by the Pickering Lumber Company and the Forest Service of the United States Department of Agriculture. This project, involving the expenditure of $22,000, was undertaken for the purpose of checking a rising epidemic of the western pine beetle in commercially valuable timber over an area of 45,000 acres. It was necessary that the work should be completed during the winter months, as conditions in this area become highly unfavorable for insect control operations during the spring.

As soon as the records of low air temperatures from a weather instrument installed at the control camp became available, it was realized that infested bark containing overwintering broods of the western pine beetle

might have reached the low temperatures that are known to be fatal to this insect. A field investigation was at once started by the Bureau of Entomology, the results of which indicated that close to 65 per cent of the total beetle population within the control area had been killed by the freeze. After this condition became known, the question of continuing the project was therefore a matter for immediate consideration. To continue the control work would require the expenditure of the same amount of money as originally contemplated, as both dead and living broods in the trees would have to be burned to accomplish the killing of the one-third of the beetle population that had survived the freeze.

The decision to discontinue the project was made by the Forest Service on the basis of information secured by the Bureau of Entomology, Department of Agriculture, and the project was closed down January 5, after it had been in progress five weeks, resulting in the saving of approximately $14,000 of Federal and private funds. As the technical considerations upon which this decision was based apply to any other western pine beetle control project where similar low temperatures occur, a description of the methods and basis used in estimating the total mortality of the bark beetle population on the Badger Springs area may be useful in the future.

Temperatures Causing Winter Kill of the Western Pine Beetle.

The conditions under which insects are killed by cold differ greatly from those affecting warm-blooded animals. The larvae of the western pine beetle may become frozen hard at temperatures of from 10 to 15 degrees above zero F., but are not killed as a result and recover when

warm weather returns. Some degrees below the temperature at which the body of the insect freezes is the undercooling or lethal temperature. Once this point is reached, the protoplasm of the body is destroyed and no recovery is possible. This point, which results in the death of the insect, is a very definite one, but is different for each species. Considerable laboratory work carried on by the Bureau of Entomology a few years ago determined the bark temperatures necessary to kill the western pine beetle. The published results of this work (Miller, J.M., High and Low Lethal Temperatures for the Western Pine Beetle. Jour. Agr. Res. 43: 303-321, 1931) show that partial mortality occurs at zero F. in broods (larvae) which overwinter in the yellow pine belt of the Sierra Nevada region; mortality at—5° exceeds 60 per cent, and practically no larvae survive—10°. Larvae which had passed through the overwintering condition at Coeur d'Alene, Idaho, developed high mortality when air temperatures were reduced through the range from 0 to—10°. About 25 per cent survived a temperature of—10°, but mortality was practically complete at—18°.

These earlier studies indicate that even where severe winter temperatures occur, as in northern Idaho, the greater part of the overwintering larval broods of the western pine beetle is killed when bark temperatures reach—10°F., and that few if any survive if these bark temperatures go as low as—18°. However, all records and observations now available indicate that weather conditions producing lethal temperatures in the bark occur but rarely. Aside from this recent case there is only one record of a decisive winter kill of the western pine beetle. This was near Bend, Oregon, in December, 1924, following weather conditions somewhat similar to those at Badger Springs in 1932.

Methods Used in Determining the Amount of Winter Kill on the Badger Springs Area

During the cold spell in December the range of air temperatures on the project area was recorded by a hygrothermograph that had been installed in the control camp at Pickering Portable Mill, near Hackamore, Calif. For three days (December 10, 11, and 12) the highest temperature recorded was +12° and the lowest —19°. For only a few hours during the day did temperatures rise above zero F. Just what temperatures were actually reached in the bark of infested trees during the period cannot be determined, as no apparatus was installed to record them.

A field study of the conditions of exposure and the actual mortality that resulted was made during December by Dr. K. A. Salman of the Bureau of Entomology, with the cooperation of the Forest Service. Trees felled during the progress of control work were examined and bark sections taken at various heights on the trunks. In addition, the two spotting crews of the project were utilized in collecting samples from infested trees located on strip courses run so as to give a representative coverage of the project area. All bark samples obtained by the spotting crews were about 6 by 6 inches, taken at breast height on the tree, and selected so as to give as even distribution as possible between north and south exposures. A count of the dead and living individuals of the brood in each sample was then made. Dead and living larvae were fairly easy to distinguish within a week after the freeze, the dead ones taking on a discolored, darkened appearance. In the egg

stage, however, this distinction was not so recognizable. A few preliminary counts were made in the field, but most of the samples were examined at the Bureau of Entomology laboratory at Berkeley, where facilities were available to make these counts with considerable accuracy.

Mortality Found in Bark Samples

The basis for the brood-mortality estimates on the Badger Springs area consisted in complete counts of dead and living insects found in 133 separate bark samples. This was equivalent to the sampling of all infested trees on about two sections, or approximately 2 per cent of the project area.

In this material 64.4 per cent of the western pine beetle broods in all stages of development were dead. This mortality was found to be general throughout the project area. An appreciable kill was also found among other insects in the bark, such as the mountain pine beetle, flat-headed borers, and clerid predators.

Local factors tending to modify the actual minimum temperatures reached in the bark, as well as those of the surrounding air, no doubt vary for each infested tree, with the result that considerable variation was found in brood mortality.

The lowest mortality of the western pine beetle found in any one sample was 5.5 per cent, the highest 100 per cent. Fairly consistent correlation was found between mortality and bark thickness; i.e., the thinner the bark, the higher the mortality. Somewhat higher survival was

noted in the parent-adult and egg stages than in the larval stages of the broods. The highest mortality was found in broods of the full-grown larval stage.

General field observations indicated that mortality was higher in trees with loose bark than in those with tight bark. It was also noted in the trees examined after felling that mortality was higher toward the upper part of the trunk. Very little variation was found that could be attributed to site, slope, or difference in elevation, as the project area is comparatively level, with uniform site conditions.

Considering all the variable conditions that have entered into the results of the freeze, it is believed that the estimate of 65 per cent total mortality for the project area is conservative. One reason for this assumption is that the greater number of the bark samples were taken from the baseof trees, where the bark is thickest. In addition, during one of the two days given to the collection of samples by the spotting crews, effort was concentrated upon trees containing young brood stages, representing optimum conditions for survival. The counts from the greater part of the samples would therefore tend to lower the average mortality figure below that which actually occurred.

Factors Affecting Surviving Insects

The surviving 35 per cent of the western pine beetle population left on the area will remain in the trees for four or five months after the freeze before the insects mature and emerge to attack new trees. During this period no factors affecting the broods can in any way increase

the number of living insects, while on the other hand they will be subjected to a number of influences which are certain to increase appreciably the total mortality. Birds and insect predators within the area will be obliged to concentrate upon the surviving broods, and in addition a certain number of the larvae always die of bacterial disease and undetermined causes during the progress of brood development. It seems safe to assume that the beetle population which ultimately survives the winter and spring and emerges to start the attack of the 1933 infestation will be measurably less than the 35 per cent estimated to have survived the December freeze on the project area.

Winter Kill in Other Areas.

Samples secured by the McCloud River Lumber Company indicate that in the Cayton Valley country, about 50 miles southwest of the Badger area, only a relatively low mortality occurred during the cold spell, averaging about 28 per cent, the maximum not exceeding 75 per cent. In another area (Egg Lake and Widow Valley) on the Modoc Forest an average kill of 65 per cent was found in the bark samples, with a maximum of 100 per cent.

So far no data are available for the west slope of the Sierra Nevadas in central California; but such weather records as are available indicate that there is little possibility that air temperatures were low enough to produce killing temperatures in the bark.

It is to be expected that great variation in the percentage of mortality will be found for different localities, even within the zones where air temperatures lower than —15° have been recorded. It should be

kept in mind that bark temperatures must go down to rather definite points in order to kill insects; if the bark temperatures remain even a few degrees above these critical points, the broods survive. Local factors such as site, slope, elevation, exposure, bark thickness, and brood condition may act to modify the effect of air temperatures upon the brood so that considerable or extreme variation in the amount of kill may result in the same area and even in the same tree.

Further Work Contemplated.

As a result of this cold spell, the course of the western pine beetle infestation may be greatly modified over a considerable area in northeastern California during the 1933 season from that indicated by the surveys made during the fall of 1932. Determination of the distribution and severity of the winter kill will therefore be of much value in the consideration of further forest protection work in this region. Of even greater importance in the application of the winter-kill factor in future control projects is the need for an adequate study of the relation between bark and air temperatures, showing the lag of the bark in cooling and the differences in the minimum temperatures reached. This can be arrived at satisfactorily only by the installation of recording apparatus which will give consistent comparative temperature readings of bark and air. If a reliable correlation can be established, it should be possible in the future to estimate winter brood mortality from standard Weather Bureau records.

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ABSTRACT

The effect of climate upon the abundance of insect life in the forest is a factor in ecology that can rarely be measured by quantitative methods. In the following article, however, there is a record of the sudden depletion of the bark-beetle population over a large area in the Modoc National Forest caused by low temperatures only a few degrees below those which ordinarily occur during the winter season. Following a cold spell in December, 1932, 65 per cent of the western pine beetle broods were found to be dead. This permitted the closing down of a control project, and it will undoubtedly have a large effect upon the future course of the bark-beetle epidemic which has been developing in that region.